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INFORMATION AUTHORITY AND
INTERNAL GOVERNANCE
OF THE FIRM

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No. 98-03 July, 1998

massachusetts
institute of
technology
50 memorial drive
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Information, Authority and Internal Governance of the Firm

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MIT

rewells@mit.edu

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Abstract

A theory of optimal internal organizational structure of the firm as a problem of governing the internal trade in a firm's resources is presented and analyzed in this paper. A principal faces several agents in a multi-product organization who are differentially and privately informed about revenue prospects and quality of an organizational asset. I analyze first a "structure-less organization" in which there is free communication and coalition-formation among players including the principal. In this environment and under complete contracting, I show that when a productively-critical agent can control the allocation of his own labor services and can withold information on allocative efficiency of resources he becomes the nexus of competing interests within the organization and can thereby capture its disposable rents. This results in no loss of allocative efficency of the organization and no complete contract offered by the principal can alter this outcome in equilibrium. Information hoarding behavior is consistent with numerous observations by organizational behaviorists and economic historians.

I show that a solution for the principal is to impose an incomplete-contract mechanism, where the principal ignores efficiency-enhancing messages from agents. This mechanism functions as an *authority structure* and provides rent-extraction for the principal but decreases the allocative efficiency of the organization. I characterize how the principal optimally structures trade in resources between authority centers.

The model shows how *authority functions like "intra-organizational property rights"* in assigning to authority-holders exclusive rights of use and intra-organizationl trade over dedicated shares of the critical agent's labor services. This provides a rationale for the employment relationship: elimination of personal discretion over allocation of the critical agent's labor services becomes a pre-condition of his access to the principal's productive assets. An implication is that worker-controlled firms will not exist in cases in which productive assets must be provided by an outside principal without an external enforcement mechanism.

1. Introduction

How exactly does a firm differ from a market? The question may seem oxymoronic, but when one considers that both firms and markets must accomplish similar functions—allocating scarce resources to competing interests (competing *internal* interests in the case of a firm)—the question appears more compelling. Furthermore, indirect evidence for the importance of the question is the voluminous business literature on the topics of internal organization of activities in the firm, authority and accountability, etc.

According to Alchian and Demsetz (1972), however, such questions are fundamentally mis-guided. In their view employment relationships are characterized only by the right of the principal to hire or fire, no different than the hiring or firing of an independent contractor in a market relationship. They state,

> *It is common to see the firm characterized by the power to settle issues by fiat, by authority, or by disciplinary action superior to that available in the conventional market. This is delusion. The firm...has no power of fiat, no authority, no disciplinary action any different in the slightest degree from ordinary market contracting between any two people.*

The purpose of this paper is to show, however, that such a question is not misguided: that *authority* in the context of an *optimal organizational structure* has an explanation grounded in economic theory and which differentiates a firm from a market. Moreover, this paper develops an economic model that generates predictions that are consistent with phenomena described by economic historians of the organization of work and by organizational behaviorists. This is done by first modelling and analyzing an *apparent* counter-factual phenomenon: an organization without an authority structure in which privately and differentially informed agents within the organization are allowed to freely communicate and trade in resources owned by a principal. Such a structure-less organization is equivalent to a market and I show that it results in a rent-extraction problem for the principal. This rent-extraction problem arises when an agent witholds or *hoards* productively-useful information from others in the organization, making his labor services the center of competing interests within the organization and thereby allowing him to capture the rents of the organization.

A solution for the principal is to impose an *internal governance structure* that limits and regulates trade among agents: that governance structure assigns authority, where authority gives its holder exclusive right to direct the use and trade

of the agent's labor services. Thus, an authority structure generates a kind of *system of intra-organizational property rights.* Intra-organizational trade is limited to *authorized trade*, defined to be trade that obeys the authority structure. Furthermore, it is shown that the principal will ignore efficiency-enhancing messages from agents, implying that an optimal organizational structure diminishes the efficiency of the organization. In response to the claim by Alchian and Demsetz, it is this internal governance structure, that stipulates how employees in a firm must (or must not) trade among themselves, that differentiates a firm from a market. A more accurate distinction, however, may be between a principal-controlled firm form a worker-controlled firm: a principal-controlled firm in one in which the principal has imposed an optimal authority structure and the employment relationship, while a worker-controlled firm is one in which trade within the organization is governed by mutual agreements among workers. The latter will arise in a structure-less organization in equilibrium.

Few papers have addressed the subject of internal organization of the firm, and most of them focus on a single superordinate-subordinate relationship. Aghion and Tirole (1993) explore the limits of intervention and authority in a superordinate-subordinate relationship under employee moral hazard. Athey *et al* (1994) also analyze the allocation of decision-making in a superordinate-subordinate relationship under the existence of complementarities between information-processing and production. As well as isolating the problem to a single relationship, these papers take as exogenous questions such as how the designation of superordinate versus subordinate are made. Such a focus, however, is likely to under-estimate the problem facing an organizational planner.

This paper is closer in spirit to papers by Holmstrom (1996), Holmstrom and Milgrom (1991, 1994), and Holmstrom and Tirole (1991), where the firm is viewed as a system of "managed trade" due to moral hazard by employees (although this paper uses a mechanism-design framework). A common thread in this literature is the view that while rules of conduct within a firm do form an alternative to a pure price mechanism for the allocation of resources, that they are a *modulated* alternative: rules operate to mediate and to manage internal trade rather than to replace trade entirely and resorting to allocation by fiat. The view of the firm presented here is one of a kind of "regulated market" in which internal

trade is monitored and managed by rules and structure.[1,2] In addition, the paper is akin to the influence cost literature Milgrom (1988) and Milgrom and Roberts (1988) which show that informational asymmetries within organizations lead organizational designers to adopt rules that limit information transmission within the organization and hence diminish efficiency.

Several observations made by organizational behaviorists and economic historians on the organization of work are consistent with the model in this paper and with predictions generated by the model. The phenomenon of *information hoarding* generated here reflects numerous observations by organizational behaviorists of the tendency of people within organizations to withold information to enhance their "power", where power here is identified with the ability to capture rents in a structure-less environment. A well-cited example is Crozier's tale of maintenance engineers in a French tobacco plant who refused to provide written documentation for machinery maintenance, and which he interpreted as an instance in which workers witheld information in order to increase their power in the organization. Crozier found that the engineers had an inordinate amount of power given their formal status in the firm's hierarchy (Crozier (1964), cited in Pfeffer (1981)).[3]

[1] Holmstrom (1996), in particular, has noted that the traditional distinction between firm and market may not be so hard and fast. In his view trade via some kind of shadow cost price mechanism does occur within the firm, and that the managers of firms are best seen as "regulators of trade". This interpretation of the firm is compelling when viewed in a wider context: pure transfer pricing is the most extreme example of a situation in which the effective distinction between firm and market disappears. Other instruments of the firm such as incentive contracts, relative performance measures, competitive internal capital budgeting, etc., are clearly market-like in their use of internal competition and residual returns to generate signals and to provide incentives.

[2] A similar view of the firm as closer to a regulated market than is commonly perceived comes from the Rational Choice School of sociology. The sociologist James Coleman states that the firm should be viewed as a type of market that is rationally structured in terms of its internal organization to meet certain aims, and that its organizational structure "lies not in defining expectations and obligations, but in structuring reward systems and providing resources" (Coleman, 1990). Coleman emphasizes, however, that a firm is different from a market because it imposes a structure not found in market relationships, that it is "composed of positions to which authority is delegated, rather than to persons." Firms, he argues, should not be viewed as inflexible hierarchies but are complex authority systems that use market-like mechanisms to match persons to resources.

[3] This view of authority as ultimately linked to the allocation of resources is supported by Salancik and Pfeffer (1974) who view authority as "legitimated power" within an organization. They find that the use of power was used more in allocating resources to the extent that they were scarce.

The *apparent* counterfactural of an organization in which agents who employ the principal's assets are allowed to freely contract among themselves is consistent with the historical phenomenon known as "inside contracting".[4] Inside contracting, now discarded, was a method of organizing production in manufacturing firms often employed in the U.S. roughly between the Civil War and World War I (Buttrick (1956)). In inside contracting production was performed by contractors who used the principal's assets in production and who themselves contracted freely with other workers and contractors inside the plant, and in turn were paid on the basis of goods delivered. The practice ended when contractors were replaced by salaried foremen and employment practices were changed so that all workers were hired directly by the firm. Buttrick claims that although the inside contracting system produced high-quality goods, the demise of the inside contracting system arose because contractors witheld information on production techniques from the principal and were "...making what seemed like too much money."[5]

Contemporary organizational behaviorists have also documented allocational rigidities in firms that observe a strict hierarchical authority structure, another implication of the model. Morrill (1995) find that executives in such organizations "exhibit a *rule orientation* – so concerned are they with obeying proper bureaucratic procedure", and that 64% of executives surveyed identify getting their superior's support as the key factor in adoption of a proposal, independent of the proposal's merits. Furthemore, Morrill finds that communication in such firms tends to follow lines of authority upward and downward rather than across authority spheres. In contrast, in so-called "matrix organizations", in which there are cross-cutting lines of authority over sub-ordinates (so that authority is not exclusive), Morill finds that coalition-formation and gaming determine decisions rather than authority: "Uneven intersections of authority lead to the formation of coalitions...Interactions among matrix executives that do not involve planning, plotting, or engaging in intrigue are rare." And, "[Matrix firms] have highly dense information flows compared to mechanistic [hierarchical-authority based] firms." These observations are also consistent with an assumption of the model—

[4]Inside contracting was made known to me by Oliver Williamson well after the model in this paper was developed.

[5]Buttrick: "The history of the contract system spans the period in which....the functions which are today assigned to management were gathered up by the capitalist. [The contractor] was in charge of the labor force, the entire process of manufacture, and the design of the product which was to be sold [by the capitalist]. By the First World War, the capitalist had assumed these functions and the last contractor had been eliminated. The pattern of management control pictured in organization charts was finally approximated in the plant itself."

that coalition-formation is endemic in a structure-less organization, and with a prediction of the model— that an authority structure based on non-exclusivity is equivalent to a structure-less environment. They are also consistent with the main result of this paper: that an optimal structure seeks to limit and regulate trade among agents by endowing some agents with exclusive authority over other agents' labor services, and results in the allocative inefficiency that is an observed characteristic of hierarchical, authority-based firms.

The specifics of the model and its results are as follows. The principal owns an asset which is employed within a multi-agent organization to produce two goods. This asset must be used in conjunction with the labor services of an upstream agent and who may or may not possess private information about the cost of production.[6] Both the use of the asset and the upstream agent's labor services are infinitely divisible into shares to be allocated to the two product lines. Downstream agents within the organization are privately and differentially informed about the revenue prospects of the two goods and accrue the sales revenue from the goods. In a structure-less organization agents are allowed to communicate and contract freely among themselves and any transaction between parties is private information to the parties to that transaction. The allocation of resources and rents in this organization is then analyzed as a "trading game" in which players (agents as well as the principal) submit proposed mechanisms (correlated strategies) for the allocation of resources and rents, and any set of players who engage in a common mechanism in equilibrium is considered a coalition. The equilibrium concept here is a *coalition-proof communication equilibrium* (Moreno and Wooders (1996)), in which any mechanism adopted in equilibrium must be robust to deviations (both coalitional and individual) by its members, and where equilibria satisfy a pareto-criterion and incentive compatibility with respect to private information about revenue prospects.[7]

In the case in which the upstream agent does not possess private information about production costs and is given discretion to allocate his own labor services,

[6] The rationale for assuming specialization between an agent and an asset is the following observation by Mechanic (quoted in Pfeffer, 1981): "lower level participants [in the firm] have power that comes from specialized knowledge about the work process and access to information that higher level managers may not have."

[7] Note that although I represent the allocation problem as one involving two product lines within the organization, it is qualitatively equivalent to a single-product organization in which downstream agents must exert privately observable effort and they differ in the cost of a unit of effort. In that case the principal will tender effort-procurement contracts (incentive contracts) to the downstream agents.

I show that there is a unique equilibrum in mixing strategies in which the four players share equally (in expectation) the disposable rents of the organization. However, when the upstream agent possesses private information about production cost and has discretion over his labor services the equilibrium set collapses to a unique equilibrium in pure strategies. In that equilibrium the upstream agent generates a boundedly small amount (in terms of probability measure) of uncertainty about the cost of production, which in turn induces the downstream agents to compete for his labor services in order to resolve this uncertainty. This result implies that no feasible complete contract the principal could offer can alter the equilibrium distribution of rents.

I show that a solution to the principal's rent extraction problem is to impose an optimaly authority structure that governs and regulates trade in the upstream agent's labor services, where optimality here is defined in terms of the principal's interests. The optimal authority structure has the following characteristics:

(1) Authority is used to counter-act the rent-seeking actions of the upstream agent. This is effected by endowing the authority-holder the right to use a stipulated share of the upstream agent's labor services at the authority holder's discretion. The upstream agent's discretion in how to allocate his own services within the organization is thereby eliminated, and he becomes a *proper subordinate* within the organization.

(2) In an optimal authority structure the principal will never endow multiple downstream agents with joint authority over the subordinate, but will instead endow each downstream agent with separate and independent authority over a share of the subordinate's labor services.

(3) An authority strucure must be supported by a technology that allows an authority-holder to *voluntarily* verify to the principal any instances in which his authority has been violated (that is, someone has used his share of the subordinate's services without his permission).

(4) The principal will never determine the allocation of shares of the subordinate's services to the downstream agents based upon messages from any agent within the organization, but will instead base it on his own prior, uninformed beliefs. This result shows the *endogenous implementation of an incomplete contract* by the principal in the guise of an authority structure. That is, the principal chooses not to contract on messages (ignoring them instead), eschewing a complete contractual relationship with agents within the hierarchy and instead using an authority structure to implement actions.

(5) The optimal authority structure will result almost surely in allocative in-

efficiency in the organization.

(6) Under an optimal authority structure *authorized trade*, which means voluntary trade between authority-holders in shares of the subordinate's labor services is allowed by the principal. *Unauthorized trade*, trade in which some authority-holder's authority is violated, is forbidden.

(7) Acceptance of the authority structure by the agents is a pre-condition of the right to use the principal's asset and reported violations are grounds for termination of the right to use the principal's asset. Thus rationalizes the employment relationship, where personal discretion over agents' activities within the firm is constrained or eliminated as a condition of employment.

The rules by which authority is allocated and transactions within the firm are mediated are what I call the *internal governance rules* of the firm. Intuitively, authority in this model eliminates rent-seeking behavior by the upstream agent who possesses critical labor services and private information about production costs into a proper subordinate by eliminating his discretion in allocating his own labor services. Restricting an informed agent's discretion, despite being optimal from the principal's viewpoint, will come at an efficiency loss to the organization. Authorized trade between authority-holders will diminish the inefficiency associated with un-informed divisionalization by the principal, but will not eliminate it.

The paper is structured as follows. Section 2 contains the basic model and results on coalition-formation in the absence of an optimal organizational structure. In Section 3 I analyze an optimal authority structure within the organization and derive the multi-divisional firm as an optimal structure. In Section 4 I discuss principal-controlled versus worker-controlled firms in terms of internal governance structures. Section 5 concludes.

2. General Framework of the Model

The organization is composed of four members, P, S_1, S_2, and W, in a three-tier hierarchy. P denotes the principal, S_1 and S_2 denote two downstream agents, and W denotes an upstream agent. P, S_1, S_2, and W have quasi-linear preferences that are increasing in monetary payoffs. Each downstream agent is associated with an output: S_1 with product y_1 and S_2 associated with product y_2. These two products generate revenue schedules $r_1(y_1)$ and $r_2(y_2)$, where there are mutiple possible realizations of r_i for any y_i. I assume that there are no market interactions between y_1 and y_2. As a simplification I will also assume a common production

function for y_1 and y_2, so that the revenue schedules may be expressed as $r_1(y)$ and $r_2(y)$. ($r_1(y_1)$ and $r_2(y_2)$ now denote realizations of production levels and revenues.) S_1 and S_2 are assumed to have private information on $r_1(y)$ and $r_2(y)$ respectively, and this information arises from each agent's proximity to the point of sale of his own product. Furthermore, revenues accrue at the point of sale in the firm, so $r_1(y)$ and $r_2(y)$ are received by S_1 and S_2 respectively. Note that the term "hierarchy" here denotes stages of production rather than any superior-subordinate designation among agents.

Assume that $y \in [0, y^{\max}]$. Let $\{r(y)\} \subset \mathbf{R}^2$ represent the set of all possible realizations of the revenue schedules $r_1(y)$ and $r_2(y)$, and any $r_i(y) \in \{r(y)\}$ is increasing and concave as well as uniformly continuous in y. Let $\underline{r}\ (y) \equiv \inf_y \{r(y)\}$ and $\bar{r}\ (y) \equiv \sup_y \{r(y)\}$ and I assume that $\{r(y)\}$ is dense in some sub-set of $\mathbf{R}^2$, so that $\underline{r}\ (y)$ and $\bar{r}\ (y)$ are also uniformly continuous schedules. Also assume that $r^{\max} \equiv \max_r \bar{r}\ (y) < \infty$, $r^{\min} \equiv \min_r \underline{r}\ (y) \geq 0$. Then the schedules $r_1(y_1)$ and $r_2(y_2)$ have common support on a compact set $[\underline{r}\ (y), \bar{r}\ (y)]$. Let $g(r\ |\hat{y})$ denote the density of r conditional upon $y = \hat{y}$ with support $[\underline{r}\ (\hat{y}), \bar{r}\ (\hat{y})]$.

P owns an asset A whose use is infinitely divisible into shares. W possess a homogeneous amount of labor services that is also infinitely divisible, and denote these labor services by B. Both product lines require strictly positive shares of A and of B for production, so the allocation problem that the hierarchy must solve is the problem of allocating shares of A and B to the two product lines. Let α_i denotes the share of A, and β_i denotes the share of B, used in the production of y_i. The total amounts of A and B is normalized to 1 each. Let $\{\alpha\}$ denote the share schedule of A (increments on the closed unit interval), and likewise for $\{\beta\}$. I will assume that production is Leontief, so that $y_i = k \cdot \min[\alpha_i, \beta_i]$. That is, an equal share of W's labor services is required to implement a given share of A to any product line. As a simplification set $k = 1$. I assume that W receives zero utility outside of his relationship with the organization, and that P incurs an opportunity cost of c associated with the use of A within the hierarchy.

I will consider first a case in which W possesses no private information on the cost of production, followed by the case in which he does. This private information on the cost of producion is represented by $\theta \in R^+$, an index of the quality of asset A. The use of the share α_i is associated with a cost of production of $\theta\alpha_i$. In the

case in which θ is common knowledge, I normalize θ to be equal to 0.

There is an information barrier between P and the agents within the firm, S_1, S_2 and W: P cannot observe production or the revenues that are generated by production, nor can P observe the terms of any transactions among S_1, S_2 and W. Furthermore, any transactions among S_1, S_2 and W are perfectly observable only by the parties to the transactions. S_1, S_2 and W are collectively referred to as the "sub-hierarchy". This partition of information appears consistent with the typical distribution of information within a firm: an outside principal (i.e., shareholder) is uninformed about production and revenues, a downstream agent is informed about revenue prospects and only partially informed about the true productive abilities of upstream assets, and an upstream agent is informed about production costs but not about revenue prospects.

Any subset of the four parties can enter into agreements to transact in the organization's resources (asset A and W's labor services, B) and the revenues that accrue from them, but I assume that any agreements among parties must be self-enforcing in equilibrium. Note that all private information is *ex ante* and that there is no specific investment being made: thus the model uses an *ex ante* mechanism design, coalition-formation framework rather than a specific investment and *ex post* renegotiation framework as in the Grossman-Hart-Moore models.[8] Furthermore, I assume that P cannot enforce an initial agreement which W agrees to never engage in rent-seeking activities as a pre-condition to the right to work with A.

Although it comes at the cost of some complexity, this four-party, two-good framework allows a rich analysis of the problem of asset allocation within the firm under competing interests and coalition-formation. I argue that this could not be accomplished in a smaller, three-party model for the following reasons. In a three-person framework with two agents who each produce one good and one principal who owns a single asset (i.e., a two-level hierarchy of P, S_1 and S_2), the principal can maximize revenue by holding an optimal auction of the shares of the asset (see Melamud *et al* (1995)) In this case one gains no insight into why a firm may differ from a market. Alternatively if one considers a model in which the number of goods is reduced from two to one (i.e., a three-level hierarchy of P, S,and W) then there is no allocation problem to consider. The present structure, I believe, is the simplest structure that permits an analysis of how a hierarchy within a firm may differ from a market in asset allocation.

[8]Note that even if I allow W to invest in his specific relationship with asset B, that his zero utility level outside the hierarchy renders any hold-up threats non-credible.

2.1. The Allocation Game: Coalition-Formation and the Allocation of Assets in the Structure-less Organization

In this section I analyze an organization in which P imposes no structure on transactions within the sub-hierarchy and allows S_1, S_2 and W to freely contract among themselves. I first consider the case in which θ is common knowledge and set $\theta = 0$. Second I consider the case in which W possess private information on θ and where $\theta \geq 0$. The general problem analyzed in this section is two-fold: in the absence of a structure imposed by P, and given equilibrium behavior by P, S_1, S_2 and W, (1) how will A and B be allocated for production between y_1 and y_2; and (2) how will the revenues generated be distributed among P, S_1, S_2 and W. As noted before, I assume that P cannot observe the terms of any trade among other players.[9]

This problem is analyzed as a "trading game" in which the players, P, S_1, S_2, and W, engage in strategic behavior in the allocation of resources and rents within the hierarchy and where communication between players is unrestricted. Players communicate with one another by proposing correlated strategies (trading mechanisms) for the allocation of the assets and services as well as transfer payments. Strategies consist of messages that are reported to a mechanism and subsequent allocational actions.

Since agreements must be self-enforcing in equilibrium and since players are allowed unrestricted communication, any mechanism adopted in equilibrium must be immune to deviations by both individuals and by coalitions, where a coalition is defined to be any set of players who engage in a mutually-agreed upon correlated strategy. Let μ denote a correlated strategy (a trading mechanism) that has been adopted by the set of all players in the organization (the "grand coalition"). μ is a mapping from types reported to the mechanism to allocations of A and B and to transfer payments, taken across all four players. A set of players may deviate from μ in either of two ways: they may deviate *ex ante* by mis-representing their private information (type) in reports to the mechanism, and they may deviate *ex post* by not taking the actions stipulated by the mechanism as a function of the profile of reports. Players who deviate from μ play an alternative mechanism and thereby form a coalition. The solution concept used is the *coalition-proof communication equilibrium* (CPCE) of Moreno and Wooders (1996), and which is closely

[9] Without the non-observability assumption P can always compensate for trading between members of the sub-hierarchy by writing a contract which extracts all of the rents *ex post* from the sub-hierarchy.

related to the *correlated coalition-proof equilibrium under arbitrary communication structures* of Milgrom and Roberts (1996). A CPCE is a type of correlated equilibrium, under complete or incomplete information, in which communication between agents is unrestricted, but any correlated strategy undertaken in equilibrium must be coalition-proof in the sense that it is self-enforcing in a recursive fashion: it is immune to further self-enforcing coalitional deviations, including deviations by single individuals. Furthermore, any strategies that form a CPCE must lie in the set of rationalizable strategies.[10]

Let Ω represent the set of all players in the hierarchy, or the grand coalition, $\Omega \equiv \{P, S_1, S_2, W\}$. Let $\Phi^j \subset \mathbf{R}^2$ denote the common type-space of players S_1, S_2, and $\phi^j \in \Phi^j$ denotes the type of player $j = S_1, S_2$, and corresponds to his private information on the revenue schedule r_i.[11] Neither P nor W possess any private information given that θ is commonly known, and I will therefore impute the notional singleton type-space Φ^P and Φ^W to each one respectively. Let $\Phi = \Pi_{i\in\Omega}\Phi^i$ denote the space of all possible types and where $\Phi^{-i} = \Phi\backslash\Phi^i$. Let $\phi \in \Phi$ denote a given type-profile.

Let X^i denote the pure strategy set of player i, where $x^i \in X^i$ denotes i's allocation action and where $X = \Pi_{i\in\Omega}X^i$ lies in the space $\left[[0,1] \times [0,1] \times [2\,\underline{r}, 2\,\bar{r}]\right]^4$. Define $X^{-i} = X\backslash X^i$ as the action set of all players other than i, and $x \in X$ represents a given pure strategy profile. Let ΔG denote the space of probability measures on a set G. A correlated strategy for the grand coalition, μ, is a correspondence from a reported type-profile to actions under correlation, so that $\mu : \Phi \rightarrow \Delta X$. Let C denote the set of all correlated strategies for Ω; then $\mu \in C \subseteq \Delta X$.

A *conjecture* or *belief* of player i is a probability measure $p^i \in \Delta\Phi^{-i}$ that represents the probability distribution held by i before correlated strategies are proposed over the type profiles of other players. Let $p = \{p^i\}_{i\in\Omega}$ denote the profile of probability distributions held by players. Let $u^i(x, \phi)$ be the payoff to player i, $i \in \Omega$, of some allocation $x \in X$, where $u^i : X \times \Phi \rightarrow \mathbf{R}^+$.

Recall that a player can deviate from a given correlated strategy μ in two ways:

[10] Milgrom and Roberts as well as Moreno and Wooders show that candidate equilibrium strategies must lie in the set of strategies that survive iterated elimination of dominated strategies. For games with more than two players and in which players are allowed to correlate, Pearce (1985) shows that this set and the set of rationalizable strategies coincide.

[11] Note that although the type-space of S_1 and S_2 lies in R^2 that it will be shown that equilibrium mechanisms do not involve two-dimensional screening. Equilibrium mechanisms will instead screen on a single-dimension in increments of y.

by mis-reporting his type or by refusing to take the action stipulated by μ conditional upon the type reports. A coalition of players can deviate by collectively mis-representing their type profile or by collectively disobeying the recommendation of the mechanism. All deviations in a CPCE are evaluated on an *ex ante* basis: for every $\mu \in C$, deviations from μ are evaluated by all players before μ is proposed by any player and before any private information is received. The timing of moves in the game is given by Figure 1: (1) first, all possible deviations to all feasible correlated strategies are evaluated under symmetric information; (2) second, if a CPCE exists, a mechanism is accepted, again under symmetric information; (3) third, private information is received by S_1 and S_2; (4) fourth, reports are made to the mechanism; and (5) given the profile of reports, allocations are made.[12]

Given a correlated strategy $\mu \in C$ and given that each player does not deviate, i's expected payoff when he is type ϕ^i is his interim expected utility conditional on ϕ^i and given beliefs p^i:

$$U^i(\mu \mid \phi^i, p^i) = \int_{\Phi^{-i}} \int_X p^i(\phi^{-i} \mid \phi^i)\mu(x \mid \phi)u^i(x, \phi)$$

Now consider coalition-formation. A coalition is represented by $Q \in 2^4$, $Q \neq \emptyset$. A coalition Q carries out a deviation from μ by adopting an alternative correlated strategy μ' on its members, or μ'_Q. That is, it replaces the recommendations in μ for the members of Q, μ_Q, by the recommendations μ'_Q and resulting in a new correlated strategy μ' for the grand coalition. The coalition Q carries out a deviation by (1) choosing an alternative type profile to report according to some rule $f_Q : \Phi_Q \to \Delta\Phi_Q$, and (2) selecting an alternative action profile for Q according to some rule $g_Q : \Phi_Q \times \Phi_Q \times X_S \to \Delta X_S$. Then (f_Q, g_Q) form a deviation by the coalition Q if it is *feasible* (Moreno and Wooders, 1996):

[12] As Moreno and Wooders explain, the evaluation of strategies on an *ex ante* basis is arguably more general than the evaluation on an *ex post* basis (after private information is received and after a mechanism has been accepted but before it has been played). To see this, suppose the following *ex post* timing: (1) first, $\hat{\mu}$ accepted; (2) second, private information received; and (3) then, deviations from $\hat{\mu}$ evaluated. At this last stage, $\hat{\mu}$ has been elevated to the *status quo* agreement, without $\hat{\mu}$ having been itself tested by deviations at the first stage when it was accepted. Thus, an *ex post* timing structure can result in pareto-inefficiency because players may be unable to overturn the *status quo* agreement under asymmetric information. If, however, an *ex ante* timing structure is used, all possible gains to deviations are exhausted at the first stage and hence only correlated strategies that generate pareto-efficient outcomes are adopted in equilibrium. That is, all possible *ex post* deviations are evaluated *ex ante* and thereby made redundant at the *ex post* stage.

Definition 2.1. *Let $\mu \in C$ and $Q \in 2^4$, $Q \neq \emptyset$. A correlated strategy μ' is a feasible deviation by coalition Q from μ if there are (f_Q, g_Q) such that for all $\phi \in \Phi$ and each $x \in X$, that*

$$\mu'(x \mid \phi) = \int_{\Phi_S} \int_{X_S} f_Q(\hat{\phi}_S \mid \phi_S) \mu'(\hat{x}_S, x_{-S} \mid \hat{\phi}_S, \phi_S) g_Q(x_S \mid \hat{\phi}_S, \phi_S, \hat{x})$$

Let $D(\mu, Q)$ represent the set of all feasible deviations from μ by the coalition Q, and let $D(\mu, Q \mid p)$ represent the set $D(\mu, Q)$ restricted to prior beliefs p. A strategy $\bar{\mu}$ is *pareto-Q dominant at beliefs p* if no member of Q is worse off under $\bar{\mu}$ than under μ for any type profile, and if for at least one type profile every member of Q is strictly better off under $\bar{\mu}$ than under μ with the distribution of beliefs given by p. (This is equivalent to Moreno and Wooder's *pareto-Q dominance* concept, and it incorporates Pearce's best-response property of rationalizability.)

Definition 2.2. *For any coalition $Q \in 2^4$, $Q \neq \emptyset$ and correlated strategies $\mu, \bar{\mu} \in C$, $\hat{\mu}$ is said to be pareto-Q dominant at beliefs p if there exists no $\mu \in C$ such that*

$$U^i(\mu \mid \phi^i, p^i) \geq U^i(\hat{\mu} \mid \phi^i, p^i) \text{ for each } i \in Q, \phi^i \in \Phi^i, p^i \in p$$
$$U^i(\mu \mid \hat{\phi}^i, p^i) > U^i(\hat{\mu} \mid \hat{\phi}^i, p^i) \text{ for each } i \in Q, p^i \in p, \text{ and for some } \hat{\phi}^i \in \Phi^i$$

Definition 2.3. *For any coalition $Q \in 2^4$, $Q \neq \emptyset$ and correlated strategy $\hat{\mu} \in C$, the set of self-enforcing deviations by coalition Q from $\hat{\mu}$ at belief p, $SED(\hat{\mu}, Q \mid p)$, is defined recursively as follows:*

(i) if $\mid Q \mid = 1$, then $SED(\hat{\mu}, Q \mid p) = D(\hat{\mu}, Q \mid p)$

(ii) if $\mid Q \mid > 1$, then $SED(\hat{\mu}, Q \mid p) = \{\mu \in D(\hat{\mu}, Q \mid p) \mid \nexists [Q' \in 2^{II} \backslash Q$, $Q' \neq \emptyset$, $\tilde{\mu} \in SED(\mu, Q' \mid p)]$ such that $\tilde{\mu}$ is pareto-Q' dominant for coalition Q' with respect to μ at conjecture $p\}$.

Note that since deviations are planned before correlated strategies for the grand coalition are proposed and before private information is received, the set of rationalizable equilibria for any $Q \in 2^2$ is the set of interim-efficient equilibria. This is relevant because it will be shown that the trading game involves competition between S_1 and S_2. Hence, we should look for equilibria among the set of correlated strategies that satisfy interim-efficiency for S_1 and S_2 and are pareto-efficient for the grand coalition.

Definition 2.4. *A correlated strategy μ is a CPCE at beliefs p if no coalition $Q \in 2^4$, $Q \neq \emptyset$ has a deviation $\mu' \in SED(\mu, Q \mid p)$ such that μ' pareto Q-dominates μ.*

2.1.1. Case 1: W Possesses No Private Information on Production Cost

Define $r^1(y)$ to be the first-order statistic associated with the support $[\underline{r}(y), \bar{r}(y)]$, and $r^2(y)$ is the similarly-defined second-order statistic. Both of these variables have a well-defined density derivable from $g(r \mid y)$. Now define $\nu^1(y) = r^1(y) - yc$ and $\nu^2(y) = r^2(y) - yc$ (recalling that $y_i = \min[\alpha_i, \beta_i]$). $\nu^1(y)$ is the first-order statistic of the net rent schedule generated by production of a given level of y, and $\nu^2(y)$ is the associated second-order statistic. Let $f(x \mid y)$ denote the density of ν^2 conditional on y. Finally, let ν^* denote the expected value of $\nu^2(y)$ taken over realizations of output: $\nu^* = \int_0^{y_{\max}} \int_{\underline{r}(y)-yc}^{\bar{r}(y)-c} \nu^2(y) f(\nu^2 \mid y) d\nu^2 dy$. I term ν^* as the expected "disposable rents" in the organization: it is the *ex ante* expected rents remaining when S_1 and S_2 are held to their interim incentive-efficient levels of information rents associated with their private knowledge of $r_1(y)$ and $r_2(y)$ respectively.

Proposition 1 Assume that θ is commonly known and is normalized to 0. There exists a unique CPCE and the mechanism adopted and played in equilibrium has the following characteristics:

(i) The mechanism is incentive-compatible with respect to private information possessed by S_1 and S_2 on $r_1(y)$ and $r_2(y)$. The mechanism generates an *ex post* efficient allocations of A and B.

(ii) *Ex ante*, S_1 and S_2 each receive an expected payoff of their associated expected incentive-efficient information rents plus $\frac{1}{4}\nu^*$. P and W each receive an expected payoff of $\frac{1}{4}\nu^*$.

The proof is in the Appendix, and is based on the logic of coalition-proof equilibrium and unblocked outcomes. I provide here, however, the intuition of how the players come to agree to the equilibrium mechanism. I do this via an imputed "-mind game" in which players imagine various trading mechanisms and the induced equilibria. Through this process of imagining various mechanisms and eliminating those that are not supportable in equilibrium the players "non-cooperatively agree

to cooperate" and arrive at an agreement to play the equilibrium mechanism. Figure 2 illustrates the underlying intuition of how the equilibrium mechanism is arrived at. The first point is that an equilibrium agreement must take into account that S_1 and S_2 are strategic competitors as "buyers" of inputs for production, while P and W are strategic competitors for rents as "sellers" to S_1 and S_2,where W is the seller of B , his labor services, while P is the seller of shares of asset A. That is, any equilibrium agreement must take into account that S_1 and S_2 have conflicting interests in the allocation of inputs and that P and W have conflicting interests in their desire to each acquire rents from the tendering of the input under their control. Next, note that coalition-proofness requires that all gains to trade are exploited *ex ante*; hence, any equilibrium agreement must allocate A and B in an *ex post* efficient way. Furthermore, immunity to mis-representation of private information implies that any equilibrium agreement must give possessors of private information at least their incentive-efficient level of information rents. These two statements imply that ν^* is the level of expected rent yet to be allocated among the players. The allocation of ν^* is pinned down by the "shadow competition" between P and W. Without a competitor P (alternatively W) expects to receive all of ν^*. The presence of a competitor, however, implies that some of ν^* is dissipated in flat-subsidies (maintaining incentive-compatibility) to S_1 and S_2. Symmetry between P and W imply that they must receive equal shares of ν^* in equilibrium, and similarly for S_1 and S_2. Finally, coalition-proofness implies that ν^* must be allocated equally among the four players.

One may ask, however, whether S_1 and S_2 can sustain a collusive agreement between themselves against both sellers; that is, can S_1 and S_2 maintain a sub-coalition in equilibrium? If so, S_1 and S_2 can capture all the rents of the organization, holding P and W to 0 rents. The reason that this type of collusion cannot be sustained, however, is its lack of incentive-compatibility: in order to maintain a sub-coalition S_1 and S_2 must play among themselves a collusive mechanism which is itself subject to mis-reporting by S_1 and S_2 in equilibrium.[13]

[13]In Graham and Marshall (1987), collusive rings in second-price auctions are able to sustain collusion (that is, incentive compatible reporting to ring members) because there are non-ring members in the auction, thus making truthful reporting a dominant strategy in the auction and in the ring.

2.1.2. B is of Uncertain Quality: the Information Hoarding Equilibrium in the Structure-less Organization

Suppose, however, by virtue of his exclusive ability to operate A that W has another strategy available to him: he can induce uncertainty about θ in the other agents. That is, W's proximity to A allows him to generate private information in the form of θ. In this section I show that information hoarding of a "small" measure (in terms of probability measure) of information on θ by W will radically alter the equilibrium set and allow W to capture a greater share of the expected rents from the organization.

Let $\Theta = [\underline{\theta}, \bar{\theta}]$ be the range of possible values for θ, $\underline{\theta} \geq 0$ and $\bar{\theta} < \infty$. Assume that *ex ante* all players hold a uniform distribution $u(\theta)$ on Θ. Then define $\hat{\nu}^* = \int_0^{y_{\max}} \int_{\underline{\theta}}^{\bar{\theta}} \int_{\underline{r}(y)-y(c+\theta)}^{\bar{r}(y)-y(c+\theta)} \hat{\nu}^2(y) f(\hat{\nu}^2 \mid y) u(\theta) d\nu^2 d\theta dy$ as the *ex ante* expected disposable rents in the organization under uncertainty over θ. I define a partition of Θ of size $N \in J^+$, $q(N) \equiv (q_0(N), ..., q_N(N))$, to be a segmentation of Θ in N equal steps and dividing points between steps $q_0(N), ..., q_N(N)$, where $q_0(N) = \underline{\theta}$ and $q_N(N) = \bar{\theta}$. Next I define $\bar{N}$ to be the finest partition size such that S_i can distinguish the statement "$\theta \in q_j(\bar{N})$" from the statement "$\theta \in q_{j+1}(\bar{N})$". That is, for any partition of size $\bar{N} + k$ the statement "$\theta \in q_j(\bar{N} + k)$" is indistinguishable by S_i from the statement that "$\theta \in q_{j+1}(\bar{N} + k)$".[14] Thus, in terms of S_i's ability to distinguish different levels of θ, the message "$\theta \in q_j(\bar{N})$" is equivalent to a point-statement (e.g., "$\theta = 0.35$"). However, for any message such as "$\theta \in q_j(N)$", where $N < \bar{N}$, the receiver of that message retains some uncertainty about the actual realization of θ. Also note that a message based on the partition $N = 1$ is completely uninformative. I assume that $\bar{N} \geq 2$.[15] As before, deviations are tested and mechanisms are chosen *ex ante*. W chooses a message to communicate to the other players when he receives the private information θ and before the allocation mechanism based on reports of $r_1(y)$ and $r_2(y)$ are sent. Let N^* represent W's choice of N, and I assume that if $N^* < \bar{N}$ (W communicates an interval-statement

[14] $\bar{N}$ can be defined exactly as follows.Let e be the smallest step length discernible by S_1 and S_2. Then $\bar{N}$ is the largest N such that $(q_1(\bar{N}) - q_0(\bar{N})) - (q_1(\bar{N}) - q_0(\bar{N})) > e$.

[15] This assumption of a finest partition is a relatively weak condition. It is necessary because without it there exists no equilibrium in this case.

rather than a point-statement), that the receiver of the message revises his beliefs about θ by imputing a uniform distribution for θ over the sub-interval $q_j(N^*)$ and assigns 0 probability to the event $\theta \notin q_j(N^*)$. Define $\bar{\theta}\,(q_j(N^*))$ to be the upper bound of the interval $q_j(N^*)$.

In addition to amending this message space I also amend the time line of moves to allow an "*ex-post* re-contracting stage" after the *ex-post* transfers and allocation stage. As will become clear in the next proposition the addition of this last stage is necessary because, in equilibrium, residual uncertainty about θ will exist at the *ex-post* transfers and allocation stage (now the penultimate stage). As a result, players will wish to engage in additional message-sending and re-contracting in equilibrium, hence the addition of thethe *ex-post* re-contracting stage. This amended time line is shown in Figure 2.

The following theorem contains one of the two main results of the paper. Again, a unique CPCE exists but in this case W's ability to withold information radically alters the equilibrium distribution of rents within the organization to the detriment of P.[16]

Proposition 2 Assume W privately observes θ. There exists a unique CPCE in which $N^* = N - 1$. When θ is observed W reports a message of the form "$\theta \in q_j(\bar{N} - 1)$" to the mechanism. S_1 and S_2 then submit incentive-compatible reports based on $r_1(y)$ and $r_2(y)$ respectively and conditioned on $\theta = \bar{\theta}\,(q_j(N^*))$. Transfers and allocations are made based upon these messages at the penultimate *ex-post* transfers and allocation stage. S_1, S_2 and W will re-contract at the *ex-post* re-contracting stage, at which time W fully reveals θ to S_1 and S_2 and a re-allocation of A and B occurs under symmetric information. The *ex ante* expected payoff to W is $\frac{1}{2}\nu^*$ and correspondingly to P is 0. The *ex ante* expected payoff s to S_1 and S_2 are their *ex ante* expected information rents plus $\frac{1}{4}\nu^*$each. The allocation of A and B is *ex post* efficient.

The proof of Proposition 2 is in the Appendix but the intuition is fairly straight-forward. Again the intuition is phrased in terms of a "mind game" in which the players mentally test various mechanisms and deviations to those mechanisms. Then, subject to deviations that are supportable in equilibrium, players "non-cooperatively agree to cooperate" and thus arrive at an equilibrium mechanism. Recall from the intution of Proposition 1 that W and P are effectively

[16]The equilibrium induced is a kind of *partition equilibrium* as in Green and Stokey (1981) and Crawford and Sobel (1982).

"non-cooperatively agree to cooperate" and thus arrive at an equilibrium mechanism. Recall from the intution of Proposition 1 that W and P are effectively competitors for the rents of the organization. Hence W gains if he can diminish or eliminate that competition from P as seller of resources to S_1 and S_2. W can accomplish this if he can make the acceptance of a mechanism that allocates the rents to himself, in contrast to a mechanism that allocates the rents to P, a pareto-superior choice for S_1 and S_2. W can effect this by building into the mechanism a transaction for the sale of information on θ to S_1 and S_2. Thus W makes the full revelation of θ to S_1 and S_2 conditional on the transfer of $\frac{1}{2}\nu^*$ to W (W's original share of $\frac{1}{4}\nu^*$ plus P's original share of $\frac{1}{4}\nu^*$).

Why, however, is it necessary to have two contracting stages instead of just one as before? The reason is that W cannot fully reveal θ when he observes it (and before the mechanism play period) and still expect to capture $\frac{1}{2}\nu^*$. If he were to fully reveal θ at that point then *ex ante* it is common knowledge that at the mechanism play period he is no longer informationally advantaged relative to P—thus the equilibrium mechanism reverts to to the equal-division result of Proposition 1. Thus W fully reveals θ only after the mechanism play period. W has an incentive, however, to *minimize yet not eliminate* the uncertainty associated with θ at the mechanism play stage. This is a variant of the adverse selection problem associated with a seller who witholds information on a good for sale of Milgrom (1981). Thus he will send messages of the form "$\theta \in q_j(\bar{N} - 1)$" at the mechanism play stage. In effect W induces "just enough" uncertainty in the allocative process of the organization to insure that he is the focus of competing interests. W will then reveal θ at the re-contracting stage once S_1 and S_2 have "paid" him for his information by playing the mechanism that gives him $\frac{1}{2}\nu^*$. At this final stage since S_1, S_2 and W are re-contracting under symmetric information hence any efficient trade opportunities will be exploited.

The uniqueness and the coalition-proof nature of the equilibrium implies the following corollary:

Corollary 1 Given W possesses private information on θ, there exists no complete-contract mechanism with the sub-hierarchy that gives P an expected net payoff greater than 0.

This result implies that P *cannot counteract the strategic behavior of* W *through complete contractual means.* This is quite clear because information hoarding by W generates a unique CPCE: no other mechanism that contracts

on messages will be accepted and implemented in equilibrium by S_1 and S_2. So even if the mechanism space is expanded to incorporate multi-stage mechanisms with punishment strategies between informed agents as in Moore-Repullo (1988). W can always offer a superior contract to S_1 and S_2. Consequently, if P is to receive an expected net payoff more than 0 he must adopt a non-contractual or structural change in the organization.

2.1.3. Discussion of Results of Sections 2.1 and 2.2

In this model W's information hoarding gives him a critical precedence within the allocational equilibrium of the organization. As noted before, this phenomenon of information hoarding reflects numerous observations by organizational behaviorists of rent-seeking behavior within organizations effected by the witholding of information. Taking the case of Crozier's engineers, one can directly apply this model to explain the engineers' behavior by equating power with the ability to capture the rents of the organization (this is the interpretation of power held by Pfeffer). Note that in the model presented here there is no costly investment on the part of W as W's power arises completely from his exclusive proximity to to the production process. This is to be distinguished from the view of power as arising from firm-specific human capital investment by a worker that induces the potential for hold-up, as in Rajan and Zingales (1996) and in Rotemberg (1994). In their models, firm-specific human capital enhances the value of the firm and a principal gives rents to workers in order to induce investment.

The model here reflects entrenchment and rent-seeking type behavior rather than productivity-enhancing investment behavior. It implies the following interpretation of Crozier's example: engineers have power because they possess critical information and control over necessary labor services, where control over those labor services is the mechanism that allows them to capture information rents. As Pfeffer states:

> Such a monopoly on knowledge is acquired and maintained in large measure through various practices of nondisclosure and secrecy so that others cannot find out what or how the parties with power are doing. Expert power [French and Raven, 1968], which is the power that comes from possessing specialized expertise, is eroded quickly if others can obtain access to the expert's information (p. 113).

Pfeffer directly relates this monopoly on knowledge to the formation and sus-

tainability of coalitions within a firm.[17] He cites the existence of "power struggles" within organizations between those who attempt to enhance and preserve their power by keeping their privileged information secret and those who wish reduce that power by disseminating that information. The model in this paper has shown how information manipulation induces coalition formation: W witholds information, which then induces S_1, S_2 and W to "informationally consolidate"(in the words of Baron and Besanko). The informationally-consolidated sub-hierarchy then functions as an information-based coalition in relation to the principal, P, holding him to 0 expected net rent.

Finally, one may ask why the case in which P act as an intermediary between S_1, S_2 and W in the allocation of B is not considered; that is, the case in which P serves as an intermediary in trade by assigning shares of B on the basis of messages from S_1, S_2 and W. This type of organizational form corresponds to the "centralized" organizational structure of Laffont and Martimort (1995) and the "informational decentralization" of Baron and Besanko (1992) (although they both use a two-agent, one-principal, moral hazard framework). As they both note, such mediated trade results in a type of double-marginalization: both agents possess private information and intermediation by P means that the optimal contract between P and each of the two agents must account for two sources of rents and inefficiency. Thus Baron and Besanko note that this informationally centralized structure is less efficient in comparison to an informationally consolidated structure in which P contracts with agents who have already consolidated their private information. Free communication and trading among agents imply that this mediated structure will be knocked out in equilibrium: S_1, S_2 and W will simply collude in advance of sending their separate messages to the P and the results of Propositions 1 through 3 continue to hold.

3. The Hierarchy with a Divisionalized Authority Structure

Assume from this point onwards that the potential for information hoarding exists (that is, $\bar{N}$ is sufficiently large). I will also assume for the remainder of this paper that a sale of asset A by P is infeasible either for credit or risk reasons. The results of Section 2 clearly imply that P has a rent-extraction problem. The results of Section 2 are especially strong because they show that W's power arises from the unique equilibrium behavior of several agents. Corollary 2.5 implies that P must

[17] In particular, he cites the example of computer programmers who withold documentation of programs in order to enhance their own power within the organization.

impose some type of structural change on the sub-hierarchy in order to capture any rents from the hierarchy. In this section I show that such a structural change has the following elements:

1) The imposition of an authority structure that allocates the right exclusive of use and intra-organizational trade of some stipulated share of B, W's labor services, to the authority-holder. This authority structure is suppored by an intra-organizational monitoring technology that permits an authority-holder to *voluntarily* verify a violation of his authority to P.

2) Employment contracts offered by P to S_1, S_2 and W in which acceptance of the authority structure of the firm is a condition of access to asset A. Reported violation of the authority structure is grounds for dismissal of the agent.

It is important to note that the revelation of an authority violation to P is on an entirely voluntary basis and that the monitoring technology does not enable P to see a transaction in which the violated authority-holder voluntarily accepts a side-transfer for compliance. Hence the potential for coalition-formation still exists within the firm. Rather, authority and the monitoring technology is of use to the principal because it affects the terms and therefore the equilibrium nature of coalition-formation among S_1, S_2 and W to P's advantage.[18]

P's objective in imposing an authority structure is to eliminate W's power to capture rents from while still using his labor services. Authority in this model is much like ownership: it endows the holder the right to determine the use of the resource under his authority. The difference is that ownership attaches to the owner of an asset, where authority is endowed by the owner upon a second party. But just as violation of property rights results in legal sanctions, violation of authority results in termination of the right of the agent to use P's asset; that is, dimissal. I consider two ways in which P can endow authority to S_1 and S_2: he can endow authority to allocate B to S_1 and S_2 jointly, or he can split B into dedicated shares and endow the authority over these shares to S_1 and S_2 separately. In the case of joint authority S_1 and S_2 are like "joint owners" of B where any allocation of B must be jointly agreed upon, and I assume that any disagreements on the use of B among S_1 and S_2 must be resolved amongst themselves. In the case of separate authority S_1 and S_2 have separate and independent authority and are like "independent owners" of their respective shares.

Proposition 3 Joint authority over B endowed to S_1 and S_2 generates the same

[18]The monitoring technology and appeal of authority violations to P serve a purpose similar to that of law courts in enforcement of property rights.

equilibrium payoff as that generated by the case of no authority structure and free contracting within the sub-hierarchy (given by Proposition 2).

The proof of this proposition is found in the proof of Proposition 4. Intuitively, the purpose of the structural change is to effect collusion by S_1 and S_2 against W so that P rather than W can capture the rents of the organization. Collusion by S_1 and S_2 against W under joint authority cannot, however, be sustained in equilibrium because it is not incentive-compatible. W will again offer an incentive-compatible allocation mechanism to both $S_1$and S_2 and engage in information hoarding, resulting in the capture of the organization's rents by W. The results of Proposition 2 will continue to hold because neither S_1 or S_2 can report to P that their authority has been violated because they have jointly and voluntarily agreed to accept W's mechanism. That is, joint authority still allows W discretion over his own labor services because it provides no means by which to eliminate it. Consequently W will again accrue the disposable surplus of the firm. Thus the outcome generated by a joint authority structure is the same the outcome generated by no authority structure at all and this implies that an optimal authority structure must entail separate and exclusive authority among authority-holders.

Let $\hat{\beta}_1$ and $\hat{\beta}_2$ represent the shares of B going to S_1 and S_2 respectively under a separate authority structure. Also let k index the relative bargaining strength of S_1 to S_2 in any intra-organizational trade in shares of B, where $k \in [0, 1]$. k indexes the share of any efficiency gain that goes to S_1 in intra-organizational trade in shares of B. The following proposition is the second major result of this paper.

Proposition 4 An optimal authority structure within the hierarchy is a mechanism for the governance of intra-organizational transactions that gives independent and separate authority to S_1 and S_2 over the shares $\hat{\beta}_1$ and $\hat{\beta}_2$, where $\hat{\beta}_1$ and $\hat{\beta}_2$ are determined by P, and where P ignores messages concerning their determination from S_1, S_2 or W. Such a structure must be supplemented by a monitoring technology that allows S_i to verify to P that S_i's authority to allocate $\hat{\beta}_i$ to his own project has been violated by S_j. In the unique limit equilibrium of the set of CPCE under an optimal authority structure, W receives an *ex ante* expected payoff of 0 and P captures the disposable rents of the organization. S_1 and S_2 engage in intra-organizational trade in shares of B almost surely. The final allocation of A and B is *ex ante* inefficient almost surely and the level of inefficiency is monotonic in k.

This structure, of course, corresponds to a multi-division organizational structure in the real world, where S_1 and S_2 are divisional supervisors with authority over assets dedicated to their divisions. This is illustrated by Figure 4. P extracts rents from this multi-divisional organization by competitively tendering asset A to the divisions managers, S_1 and S_2, who each have dedicated rights to the use and intra-organizational trade of untis of B.[19]

To see how this structure eliminates W's rent-seeking behavior suppose S_2 and W agree to violate the divisionalization by allocating $\beta_2 > \hat{\beta}_2$ in return for a payment by S_2 to W, and resulting in an allocation to S_1 of $\hat{\beta}_1 < \beta_1$. That shortfall in B to S_1 lowers S_1's expected revenues and his expected payoff under P's competitive allocation mechanism for A. Hence S_1 will report this violation of the divisional boundaries to P unless compensated by S_2. Consequently in order to effect any allocation of B that differs from $(\hat{\beta}_1, \hat{\beta}_2)$, S_1 and S_2 need only engage in transfers among themselves, and not with W. If W were to refuse to obey the allocation of B agreed upon by S_1 and S_2 then at least one of the supervisors has the incentive to report to P that his authority over his share of B has been violated. The result is that W has lost his ability to induce competition between S_1 and S_2 for his services and thereby capture rents.

Note, however, that two questions remain (1) Can W still capture rents via information witholding despite his loss in control over the allocation of his own labor services; and (2) given the Leontief production in A and B, can P be assured that his mechanism is accepted and that *ex post* trade in complementary shares of B will occur? I'll consider the first question first, assuming that the answer is affirmative for the second question. The threat that W holds is that by witholding θ, S_1 and S_2 are subject to common uncertainty in their bidding for asset A. Knowledge of θ before bidding for A is of value to both S_1 and S_2 under divisionalization, and W would ostensibly threaten to withold θ in order to capture rents. Suppose there is a three-player agreement in which S_1 and S_2 each offer W a payment of \$1 in return for the information θ. Additionally, they will in equilibrium agree to play P's incentive-compatible mechanism for the allocation of A. Note, however, that S_1 and S_2 will agree to deviate from their original agreement with W in equilibrium. They will deviate to an agreement in which S_1 and S_2 each offer W a payment of $\$1-\varepsilon$, and agree to compete among themselves for the saved 2ε via competitive bidding for A. That is, S_1 and S_2 would each prefer to compete for A using the output valuation function $r_i(y) - y \cdot (c+\theta) - (1-\varepsilon)$

[19] The allocation of capital based on competition between divisions on rates of return is an example of such a mechanism.

rather than the output valuation function $r_i(y) - y \cdot (c + \theta) - 1$ because the former valuation function has a higher probability of resulting in a positive level of production than the latter valuation function. This illustrates the importance of c, P's exogenous opportunity cost of his asset versus 0, the value of W's outside option. This logic extends so that any promised payment to W by S_1 or S_2 for the revelation of θ in excess of 0, W's outside option value, is not sustainable in the limit in a CPCE because it is not an incentive-compatible agreement given that S_1 and S_2 will compete for the allocation of A.

Now turn to the second question posed. Since shares of B cannot be allocated by an incentive-compatible mechanism, shares of A will now perform that function in equilibrium *only if ex post* trade in complementary shares of B occurs. Suppose S_1 and S_2 bid competitively for $\{\alpha\}$ and that in the resulting allocation $\alpha_1 = \frac{3}{4}$, $\alpha_2 = \frac{1}{4}$. Then in equilibrium S_1 and S_2 will engage in the trade of $\beta = \frac{1}{4}$ at a transfer no more than $r_2(\frac{1}{4}) + k\left(r_1(\frac{1}{4}) - r_2(\frac{1}{4})\right)$ to S_2, where the last term reflects S_2's share of the efficiency gain from intra-organizational trade in B. Efficient renegotiation between S_1 and S_2 means that the complementary shares of B will in fact be traded in equilibrium. (Recall that there is no two-sided asymmetric information at this point that might preclude efficient trade.) This also implies that S_1 and S_2 have correlated values in their bidding for $\{\alpha\}$, a degree of correlation that depends positively or negatively on k depending upon which manager has the excess demand for B *ex post*. This mechanism then is equivalent to an auction of shares of A in which the bidders have correlated values and P would optimize by using an open, ascending bid auction (an English auction) of $\{\alpha\}$ as his allocation mechanism. Hence in a CPCE P will offer such a mechanism for the allocation of A while S_1 and S_2 will agree to trade shares of B *ex post* using the index of bargaining power k and to hold W to an information rent of 0.

How are $\hat{\beta}_1$ and $\hat{\beta}_2$ optimally determined? Because P is uninformed with respect to r_1, r_2 and θ, without additional information P will divisionalize the allocation of B evenly across the two products, so that $\hat{\beta}_1 = \hat{\beta}_2 = \frac{1}{2}$. Would P instead set $\hat{\beta}_1$ and $\hat{\beta}_2$ according to messages sent from the sub-hierarchy? Again, the problem of collusion against P arises: S_1, S_2 and W are able to collude against P if P divisionalizes according to their messages because the messages would communicate the allocation that S_1, S_2 and W desire. That is, W would again withold information on θ and induce competition for B among S_1 and S_2 and messages from S_1, S_2 and W to P on the desired allocation of A and B would simply implement W's preferred mechanism. This implies that optimal divisionalization cannot be based on messages from S_1, S_2 and W and must instead be

based on P's uninformed estimates. Uninformed divisionalization, however, generates allocational inefficiency in equilibrium almost surely. With probability 1 the divisionalization $\hat{\beta}_1 = \hat{\beta}_2 = \frac{1}{2}$ is inefficient and *ex post* trade is distorted by the factor k. Consequently double-marginalization will occur and inefficiently few shares of B will be traded intra-organizationally. An optimal authority structure therefore lowes the allocative efficiency of the organization almost surely.

The intra-organizational property rights over divisionally-dedicated assets form the basis of what I term *authorized trade* within the firm. That is, authorized trade is trade in the organization's assets that obeys the authority structure: the right to trade is limited to those who hold authority over the asset, and forbidden to those who may be able to exert some form of *de facto* control over the firm's assets. Thus, any trade between S_i and W that effects a transfer of S_j's divisional assets without S_j's approval represents *unauthorized trade* within the firm and is therefore subject to sanctions by P because, left unchecked, would allow W to capture the disposable surplus of the firm through information hoarding. The model predicts that authorized trade, on the other hand, will not be discouraged by P because it is necessary in order to implement his rent-extraction mechanism and because it mitigates—but does not eliminate—the allocative inefficiency caused by P's uninformed divisionalization.

4. On Principal-Controlled vs. Worker-Controlled Firms

I turn now to two important questions: (1) how does P impose an optimal authority structure on agents within the organization; and (2) why does P not solve his rent-extraction problem by selling A to agents within the organization rather than imposing an inefficient organizational structure.

Take the first question first. The structure-less organization of Section 2 corresponds to an organizational form in which P sub-contracts with S_1, S_2 and W via a market-based relationship. As in the inside contracting form of organization found in the pre-industrial U.S., S_1, S_2 and W operate as independent agents who lease the use of A from P and who have the right to set the terms of transactions among themselves. That is, as independent agents S_1, S_2 and W can set their own *internal governance structure*, the rules that stipulate how internal trade is conducted. The mutual asset that is required to conduct trade in this structureless organization means that it is equivalent to a worker-controlled firm.

This is clearly different from a principal-controlled firm where P sets the internal governance structure of transactions within the organization. So to answer

the first question, it is by virtue of his ability to limit who has access to A that P can impose an authority structure on S_1, S_2 and W. This explains the employment relationship, where right-of-access to A is equivalent an employment relationship. Termination of employment is termination of the right of access to A, and will be a consequence of a reported violation of the principal-imposed authority structure.

Another meaningful distinction brought out by this model is the difference between a firm with employment contracts and a sub-contracting hierarchy. In the latter as contractors and sub-contractors, S_1, S_2 and W have the right to set their own internal governance structure, so that the structure-less organization is equivalent to a sub-contracting hierarchy. The former of course is the principal-controlled firm where employment functions as an enforcement device.[20]

This model of govenance structures within the firm provides an answer to the question long-asked of employment relationships: why are many employment relationships marked by the pre-condition for employment that an employee giving up his or her right to direct their own activities? And what induces employees to accept this loss of autonomy? According to the implications of the model, loss of personal autonomy is a pre-condition of *some* employment relationships because it supports an optimal authority system. Here we have seen that P will require that W relinquish his right to decide how he allocates his work among S_1 or S_2 in return for employment, allocating instead authority over W's services to S_1 and S_2. Note, however, that this pre-condition for employment is required only of W but *not* of S_1 or S_2 : the difference being that P can induce S_1 and S_2 to reveal their private information (and hence can limit their information rents) but he cannot induce W to reveal. Thus the model predicts that within the firm that the possession of authority and personal discretion are complementary attributes.

The second question is always one which confronts agency models; the results in this paper, however, do make it a more compelling question than usual. It is clearly pareto-efficient for P to sell A to agents within the organization. But if the

[20]The distinction between the firm versus a collection of independent sub-contractors is similar to the distinction made in Kreps (1985) between "hierarchical transactions", where certain terms are left unspecified and are resolved *ex post,* and "specified transactions" in which the terms of the contract are specified at the date of contracting. A "hierarchical transaction" in the Kreps-sense corresponds to a firm here, where a firm defines the scope of transactions over which a principal can impose a governance structure that assigns to the principal the right to govern transactions among agents within his firm. On the other hand, a "specified transactions" in the Kreps-sense corresponds to a a view of the hierarchy as a collection of independent sub-contractors, where the terms of the contract between the principal and the other agents are specific and limited to things such as price and quantity.

usual considerations of risk-aversion and/or credit constraints arise and make such a sale infeasible then the model predicts that P will instead impose an optimal but inefficient authority structure on the agents.

5. Conclusion

In this has shown that when an agent has the ability to withold information that is desired by other agents within the sub-hierarchy that information-hoarding permits him to capture the disposable surplus of the organization *regardless of the contract that the principal offers.* This implies that the principal must adopt a non-contractual or structural approach to alter the distribution of rents within the organization. I show that in an optimal organizational structure the principal ignores messages regarding the efficient re-allocation of assets across boundaries of authority. *In effect, by refusing to contract on information available to him, the principal prefers an incomplete-contracting approach to agents within the hierarchy,* where actions are directed by authority rather than by contractual terms. The model provides a rationale for the employment relationship, where termination is used to enforce adherence to the authority structure.

In a broader context, this theory of the optimal organizational structure of the firm helps to reconcile a long-standing theoretical conflict in the area of organizational behavior. In the "Political School" of organizational behavior of March (1962) and Pfeffer (1981), it is posited that certain groups or coalitions within the firm are the basis for the way it functions, and power accrues from the control of firm resources (the "resource dependence theory of power"). According to the Political School, firms are not run in the interest of profit-maximization, but in the interests of certain, powerful individuals. This has been in conflict with the earlier, axiomatic "Rational School" of Simon, where firms are run with the objective of profit-maximization. The theory presented here can reconcile and encompass these two theories: that is, it is posited here that within a structure-less environment individuals within the firm will engage in coalitional behavior based upon their control of resources, and an optimal (equivalently, rational) organizational structure will manage and direct this behavior in order to maximize the rent-extraction capability of the principal.

6. Appendix

Before proceeding to prove the propositions in the paper, I first establish some preliminary results on efficient trading mechanisms for shares of assets.

6.1. Trading Mechanisms

I. Trading Mechanism for Shares of One Asset of Certain Quality

Assume that only one asset, called K, is used in the production of y_1 and y_2. Like A and B, K is infinitely divisible and k_i represents the share of asset K used in production of y_i, $k_i \in [0,1]$. Assume that $y_i = k_i$ and K has the opportunity cost c. Then $\nu^1(k) = r^1(k) - kc$ is the first-order statistic of net revenue on support $[\underline{r}(k) - kc, \bar{r}(k) - kc]$ associated with the from production using asset K. Let $\nu^2(k)$ represent the associated second-order statistic of net revenue, and $f(\nu^2 \mid k)$ is its density function. Then define $\nu^* = \int_0^{y_{\max}} \int_{\underline{r}(k)-kc}^{\bar{r}(k)-kc} \nu^2(k) f(\nu^2 \mid k) d\nu^2 dk$. ν^* is the expected value of the second-order statistic of the net revenue schedules generated by use of J.

Let $dk \mid_{\hat{k}}$ denote the increment dk evaluated at share $\hat{k}$, and the value of $dk \mid_{\hat{k}}$ to S_i is $(dr_i \mid_{\hat{k}} - c \cdot dk) \equiv x_i \mid_{\hat{k}}$. Let $J(x \mid_{\hat{k}})$ denote the distribution of $x \mid_{\hat{k}}$ on $[d\underline{r}(k) \mid_{\hat{k}} -kc, d\bar{r}(k) \mid_{\hat{k}} -kc]$ The value to S_i of K is the net revenue schedule $\{r_i(k) - kc \mid k : 0 \to 1]\} = \{x_i\}$. Let $\{b_i(s_i \mid x_i)\}$ denote S_i's submitted bid schedule for shares of J and $db_i(s_i \mid x_i) \mid_{\hat{k}}$denotes S_i's bid for the increment $dj \mid_{\hat{k}}$, where $\{b_i(x_i \mid x_i)\} = \{b_i(x_i)\}$.

Claim 1 Under self-enforcing agreements and under certain quality an optimal trading mechanism for the seller of K is an absolute second-price auction of the share schedule $\{k\}$ in which bids take the form of a bid schedule $\{b_i(s_i \mid x_i)\}$. This is an *ex post* efficient mechanism and implementable in dominant strategies.

Proof Under certain quality S_1 and S_2 have independent private values, hence sealed-bid and open-bid transaction mechanisms are equivalent. Self-enforcement of agreements implies that a reserve price by the seller of J in excess of his opportunity cost of c is unenforceable. Fix an increment of J, $dk \mid_{\hat{k}}$. Then under a second-price allocation rule $dk \mid_{\hat{k}}$is awarded to S_i at price $db_j \mid_{\hat{k}}$ if $db_i \mid_{\hat{k}} > db_j \mid_{\hat{k}}$. It is a well-known result that $db_i(s_i \mid x_i) \mid_{\hat{k}} = db_i(x_i) \mid_{\hat{k}}$ is a dominant strategy under a second-price rule and that the resulting allocation is *ex post* efficient. By the Revenue Equivalence Theorem the expected

revenue to the seller of a second-price auction is the same as a first-price auction (assuming symmetric bidding strategies, which is the case here). Hence, a second-price absolute auction in bid schedules for $\{j\}$ is an optimal mechanism implementable in dominant strategies under self-enforcement.||

Claim 2 The maximum expected value of an efficient allocation mechanism to the seller of K is ν^*.

Proof Assume S_i wins $dk \mid_{\hat{k}}$. His expected information rent is $\frac{\int_c^{x^1} F(s|\hat{k})ds}{F(x^1|\hat{k})} = x^1 \mid_{\hat{k}} - E(x^2 \mid_{\hat{k}})$, where $x^1 \mid_{\hat{k}}$ and $x^2 \mid_{\hat{k}}$ are the first-order and second-order statistics associated with $x \mid_{\hat{k}}$. Define $\bar{x} \mid_{\hat{k}} = d\bar{r} \mid_{\hat{k}} - c \cdot dk$ and $\underline{x} \mid_{\hat{k}} = d\underline{r} \mid_{\hat{k}} - c \cdot dk$. The expected rent to the seller of $dk \mid_{\hat{k}}$ before bidding begins is $2 \int_{\underline{x}|_{\hat{k}}}^{\bar{x}|_{\hat{k}}} \left(s - \frac{1-F(s|\hat{k})}{f(s|\hat{k})}\right) F(s \mid \hat{k}) f(s \mid \hat{k}) ds = \int_{\underline{x}|_{\hat{k}}}^{\bar{x}|_{\hat{k}}} x^2 \mid_{\hat{k}} f(x^2 \mid \hat{k}) dx$, the expected value of the second-order statistic of net revenue associated with $dk \mid_{\hat{k}}$. Integrating this expression of the expected rent per dk over $\{k\}$ gives the expression for ν^*.||

II. Efficient Trading Mechanism for Shares of One Asset with Uncertain Quality and Uniform Priors

Assume the net revenue function is now $r(k) - k(c + \theta)$, where S_1 and S_2 both hold uniformly-distributions of θ on $[\underline{\theta}, \bar{\theta}]$.

Claim 3 Under uncertain quality with uniform priors held by S_1 and S_2 an optimal mechanism is an absolute second-price auction of the share schedule $\{k\}$. This mechanism is *ex ante* inefficient but *ex post* inefficient with positive probability.

Proof Since S_1 and S_2 are identically informed about θ, there is no gain associated with an open auction of K. Hence the seller will prefer a second-price auction, just as in the case of certain quality (McAfee and McMillan). As before the mechanism implementable in dominant strategies; it is *ex ante* efficient but is now *ex post* inefficient with positive probability. To see this note that S_i will bid for share $dk \mid_{\hat{k}}$if $(dr_i \mid_{\hat{k}} - (c + E(\theta))dk) \equiv E(\hat{x}_i) \mid_{\hat{k}} \geq 0$. However, in the event S_i bids for $dk \mid_{\hat{k}}$with positive probability $\hat{x}_i \mid_{\hat{k}} \equiv (dr_i \mid_{\hat{k}} - (c + \theta)dk) < 0$. Hence the mechanism, despite awarding $dk \mid_{\hat{k}}$ to the buyer with the highest expected value, may result in an inefficient *ex post* allocation.||

6.2. Proof of Propositions

Proof of Proposition 1 Any mechanism accepted and played in a CPCE must satisfy (1) incentive-compatibility with respect to r_1 and r_2 and (2) *ex ante* pareto-efficiency (immunity to deviations by the grand coalition Ω under symmetric information when mechanisms are being evaluated) and (3) immunity to individual and coalitional deviations (immunity to individual and coalitional deviations after mechanism is accepted). Let $C_1 \subset C$ represent the set of feasible mechanisms that satisfy (1), $C_2 \subset C$ represent the set of feasible mechanisms that satisfy (2), and $C_3 \subset C$ represent the set of feasible mechanisms that satisfy (3). It is clear that $C_1 \cap C_2 \neq \emptyset$ since a second-price auction of A with equal corresponding shares of B allocated *ex post* satisfies (1) and (2).

For any $\mu \in C$ and any $Q \subset \Omega$ let μ_Q denote the strategies for the sub-coalition Q. Restrict attention to $\mu^1_{\{S_1,S_2\}}$ such that $\mu^1 \subset C_1$. Let $\pi^{S_i}(\hat{\phi}_i, \phi_i, \phi_j \mid \mu^1)$ be S_i's payoff to reporting $\hat{\phi}_i$ when his type is ϕ_i and S_j reports ϕ_j under mechanism μ^1. Then

$$\pi^{S_i}(\hat{\phi}_i, \phi_i, \phi_j \mid \mu^1) = u_{s_i}\left(z(\hat{\phi}_i, \phi_i, \phi_j) \mid \mu^1\right) + t_i(\hat{\phi}_i, \phi_j \mid \mu^1)$$

where $u_{s_i}\left(z(\hat{\phi}_i, \phi_i, \phi_j) \mid \mu^1\right)$ represents S_i's utility from the induced allocation $\left(z(\hat{\phi}_i, \phi_i, \phi_j) \mid \mu^1\right)$ and $t_i(\hat{\phi}_i, \phi_j \mid \mu^1)$ represents the corresponding transfer to/from S_i. Then $\mu^1 \subset C_1$ implies that the following differential equation holds:

$$\frac{\partial u_{s_i}\left(z(\hat{\phi}_i, \phi_i, \phi_j) \mid \mu^1\right)}{\partial z} \frac{\partial z}{\partial \hat{\phi}_i} \Big|_{\hat{r}_i = r_i} = -\frac{\partial t_i(\hat{\phi}_i, \phi_j \mid \mu^1)}{\partial \hat{\phi}_i} \Big|_{\hat{r}_i = r_i} \tag{6.1}$$

Since $y_i = \min[\alpha_i, \beta_i]$, we can treat A and B as a single asset K, with opportunity cost c. For any $dk \mid_{\hat{k}}$, Equation (1) is equivalent to the following condition:

$$\left(x_i \cdot \frac{\partial F(\hat{x}_i)}{\partial \hat{x}_i} - \frac{\partial t_i(\hat{x}_i, x_j)}{\partial \hat{x}_i}\right) \Big|_{x_i = \hat{x}_i, \hat{k}} = 0 \tag{6.2}$$

where $F(\hat{x}_i \mid_{\hat{k}})$ is the probability that S_i receives $dk \mid_{\hat{k}}$given the report $\hat{x}_i \mid_{\hat{k}}$. Thus any $\mu^1 \subset C_1$ must obey Equation (2) at every point of $\{k\}$.

Let Z represent the set of feasible allocations. For any $\mu^2 \subset C_2$, it must be that $z(\phi \mid \hat{\mu}) = \underset{z \in Z}{\arg\max} \sum_{i \in \Omega} E_{\phi \in \Phi} (u_i(z(\phi \mid \hat{\mu}))$. Denote the solution to this $z^*(\phi \mid \mu^2)$. Thus any $\mu^2 \subset C_2$ must satisfy the condition that the probability of assigning $dk \mid_{\hat{k}}$ to S_i is increasing in his relative valuation, $\frac{x_i|_{\hat{k}}}{x_j|_{\hat{k}}}$. This is satisfied when the probability of assigning $dk \mid_{\hat{k}}$ to S_i when $x_i \mid_{\hat{k}}$ is reported is $F(x_i \mid_{\hat{k}})$, the probability that $x_i \mid_{\hat{k}}$ is the first-order statistic among the distribution of $x \mid_{\hat{k}}$. Thus for any $\mu^{12} \subset C_1 \cap C_2$ must satisfy Equation (2). This implies that $z^*(\phi \mid \mu^{12})$ generates a total expected net surplus of $\nu^* + \int_0^{y^{\max}} \frac{\int_c^{x^1} F(s|k)ds}{F(x^1|k)} dk$.

Consider any $\mu^{123} \subset C_1 \cap C_2 \cap C_3$. I claim that any μ^{123} must allocate ν^* by equal division among $\{S_1, S_2, P, W\}$; that is $\{\frac{1}{4}\nu^*, \frac{1}{4}\nu^*, \frac{1}{4}\nu^*, \frac{1}{4}\nu^*\}$. Suppose not, and the allocation $\{\frac{1}{8}\nu^*, \frac{3}{8}\nu^*, \frac{1}{4}\nu^*, \frac{1}{4}\nu^*\}$ is proposed instead. Then S_1 can form a blocking coalition with P and W to block such an allocation by redistributing $\frac{3}{8}\nu^*$ away from S_2 to S_1, P, and W. Note that any redistribution of S_2's share to S_1, P, and W must itself in equilibrium be immune to further deviations among $\{S_1, S_2, P, W\}$. Hence any unblocked allocation must be an equal division allocation of ν^*. Next note that any μ^{123} must incorporate a second-price share auction of K since a first-price share auction results in inefficient allocation with positive probability due to bid-shaving, and any *ex post* inefficient allocation is subject to renegotiation.

Lastly note that since production is Leontief in A and B, P and W are really competing to be the auctioneers of the composite asset K and they compete by offering equivalent second-price share auctions. Hence S_1 and S_2 will randomize equally between jointly accepting P's mechanism and jointly accepting W's mechanism, which implies that P and W must randomize the offering of entry subsidies $\{\frac{1}{2}\nu^*, \frac{1}{2}\nu^*\}$ and $\{0, 0\}$ with equal probabilities in equilibrium.||

Claim 4 $\hat{\mu} \in C$ can block any $\tilde{\mu} \in C$ if any only if $\hat{\mu} \in C_1 \cap C_2 \cap C_3$ but $\tilde{\mu} \notin C_1 \cap C_2 \cap C_3$.

Proof The "if" statement is obvious. Assume $\hat{\mu}$ blocks any $\tilde{\mu} \in C$. If $\hat{\mu} \notin C_1 \cap C_2 \cap C_3$ then there exists some $\tilde{\mu} \in C_1 \cap C_2 \cap C_3$ that blocks $\hat{\mu}$ since by Proposition 1 $C_1 \cap C_2 \cap C_3 \neq \emptyset$, which is a contradiction. Also if $\hat{\mu} \in C_1 \cap C_2 \cap C_3$ and $\tilde{\mu} \in C_1 \cap C_2 \cap C_3$ then $\hat{\mu}$ cannot block $\tilde{\mu}$ by definition of a

CPCE.||

The proof of Proposition 2 now follows. Recall that W is now in possession of private information on θ. I claim that there exists an N' such that for $\bar{N} \geq N'$ and for any $\mu \in C_5$ that W engages in strategic information hoarding and revelation; that is, $1 < N^* < \bar{N}$. Let $(C_{123} \mid N)$ denote the set $C_1 \cap C_2 \cap C_3$ conditioned on information based on the information partition of size N on Θ held by S_1 and S_2 before the allocation mechanism is played. That is, S_1 and S_2 possess information of the form "$\theta \in q_j(N)$" before the allocation mechanism is played. By Claim 4 W can block any $\tilde{\mu} \in C$ with some $\hat{\mu} \in C$ if $\hat{\mu} \in (C_{123} \mid \hat{N})$ and $\tilde{\mu} \in (C_{123} \mid \tilde{N})$ if $\hat{N} > \tilde{N}$. Since P can only offer a mechanism μ such that $\mu \in (C_{123} \mid 1)$ when W completely witholds information W can block any μ offered by P with some $\hat{\mu} \in (C_{123} \mid \hat{N})$ where $\hat{N} > 1$. Hence $N^* > 1$ if $\bar{N} \geq N'$.

I now claim that $N^* < \bar{N}$ if $\bar{N} \geq N'$. Note that if W offers $\hat{\mu} \in (C_{123} \mid \bar{N})$ then after θ is revealed to S_1 and S_2 but before $\hat{\mu}$ is played that there exists some mechanism $\mu \in (C_{123} \mid \bar{N})$ offered by P that $\hat{\mu}$ cannot block. Hence W will not offer information to S_1 and S_2 based on partition size $\bar{N}$ before the allocation mechanism is played, and $N^* < \bar{N}$ if $\bar{N} \geq N'$.

I know claim that $N^* - 1 = \bar{N}$ if $\bar{N} \geq N'$. Assume $N^* = \bar{N} - k$, $k \geq 2$, and S_1 and S_2 have received the message "$\theta \in q_j(N^*)$". Let $\underline{\theta}(q_j(N^*))$ denote the lower limit of this interval and $\bar{\theta}(q_j(N^*))$ denote the upper limit. Now for any $q_j(N^*)$ there exists a set of intervals $\{q_a(N^*+1), q_{a+1}(N^*+1), ..., q_{a+n}(N^*+1)\}$ that covers $q_j(N^*)$. Let this set be the smallest set that covers $q_j(N^*)$ and denote it E. Then for any $\theta \in q_j(N^*)$ W could instead have communicated a message using one of the intervals in E and still retained residual uncertainty on θ. Hence by choice of $q_j(N^*)$ rather than $q\,(N) \in E$, S_1 and S_2 impute the event $\theta \in [\bar{\theta}(q_{a+n-1}(N^* + 1)), \bar{\theta}(q_j(N^*))]$. Since the value of $\{\beta\}$ to S_1 and S_2 is decreasing in θ; W will instead choose an information partition of size $N^* + 1$. This contradicts the assertion that N^* was optimal for W. The rest of the proof of the claim follows by induction on k.

S_1 and S_2 will submit messages to the allocation mechanism of the form "$r_i(y) - (c + \bar{\theta}(q_j(N^*)))y$". Since $\theta < \bar{\theta}(q_j(N^*)$ almost surely, there is inefficiently low procurement of A and B via the allocation mechanism played at the *ex post* transfers and allocation phase. Hence with probability 1 the players will wish to re-contract inducing the re-contracting stage. At the stage W wish to fully reveal θ to induce additional demand for B. Hence at

the re-contracting stage all players are symmetrically informed with respect to $r_1(y), r_2(y)$ and θ. As a result all gains to trade will be exploited and the *ex post* allocation of A and B is efficient.||

Claim 5 Under an optimal mechanism and no sale of asset A P imposes an *ex ante* inefficient mechanism on the organization.

Proof Since under information hoarding C_{123} consists of a singleton mechanism, P wishes to implement a $\mu \notin C_{123}$. Consider the restriction on sale of A, and let $\hat{C}$ denote the set of all feasible mechanisms remaining after exclusion of the sale of A as a strategy. Then any μ a CPCE must lie in $\hat{C}$. Let μ^* denote a CPCE and assume that it exists. Then clearly $\mu^* \in C_1$ and $\mu^* \in C_3$. If $\mu^* \notin C_1$ then with no loss μ^* can be replaced by a $\mu^{**} \in C_1$; if $\mu^* \notin C_3$ then by definition μ^* is not an equilibrium. Hence if $\mu^* \notin C_{123}$ and $\mu^* \in \hat{C}$ it must be that $\mu^* \in C_1 \cap C_3 \cap \hat{C} \backslash C_2$. This establishes that P must impose inefficiency on the organization to extract positive expected rents.

Claim 6 An optimal mechanism does not permit the allocation of $\{\alpha\}$ and $\{\beta\}$ based on agents' messages. An optimal mechanism allocates $\{\beta\}$ to S_1 and S_2 based on P's uninformed beliefs while the allocation of $\{\alpha\}$ in an optimal mechanism is based on messages from S_1 and S_2 and permits *ex post* trade between S_1 and S_2 in $\{\beta\}$. An optimal mechanism must implement voluntary reporting by S_i of unapproved use of β_i by S_i and resulting sanctions.

Proof If P implemented the allocation of $\{\alpha\}$ and $\{\beta\}$ via messages from S_1 and S_2 he would simply implement the unique information. Recall that $\hat{\beta}_1, \hat{\beta}_2$ are the shares of B stipulated by P to the two divisions and given my assumptions $\hat{\beta}_1 = \hat{\beta}_2 = \frac{1}{2}$. Since production is Leontief no *ex post* trade in $\{\beta\}$ implies that it must be that $\hat{\alpha}_1 = \hat{\beta}_1, \hat{\alpha}_2 = \hat{\beta}_2$. Although this allocation is incentive-compatible and therefore satisfies the incentive-compatibility requirement of a CPCE, it is not optimal for P. An allocation of $\{\alpha\}$ based on messages is optimal for P if S_1 and S_2 can acquire the necessary complementary shares of B *ex post* but without implementing the information hoarding equilibrium. Hence P will permit *ex post* trade in $\{\beta\}$ if it does not implement the information hoarding equilibrium. Unrestricted trade in $\{\beta\}$ implements the hoarding equilibrium and therefore cannot be part of an optimal mechanism. Restricted trade, however, must obey the constraint represented by C_3: that is, it is not subject to individual and

coalitional deviations to unrestricted trade. Hence an optimal mechanism must make reporting of unrestricted trade an equilibrium strategy.

Claim 7 An optimal mechanism endows S_1 and S_2 exclusive right to use and trade intra-organizationally their respective shares $\hat{\beta}_1$ and $\hat{\beta}_2$.

Proof Exclusive right to use and trade intra-organizationally means that the report of a violation of this exclusivity will be reported by the party being violated unless compensated. So any agreement among agents in the organization to engage in unrestricted trade is subject to individual deviations (reporting this to P) and hence cannot form part of a CPCE under an optimal mechanism. Note that there is of course a coalitional deviation possible if asset sale of A were allowed: S_1, S_2 and W would purchase A from P and would eliminate the authority structure.

Claim 8 For any k an optimal mechanism is *ex ante* inefficient where in expectation inefficiently few shares of B are traded intra-organizationally

Proof There will be no allocative inefficiency only in two events: (1) the division manager with the excess demand for shares of B has all the bargaining power, which then $k = 0$ or 1 occurs with probability $\frac{1}{2}$; or (2) the zero probability event occurs in which $\hat{\beta}_1 = \hat{\beta}_2 = \frac{1}{2}$ is the efficient allocation.

Claim 9 In the limit equilibrium of the set of CPCE under the optimal mechanism W receives an expected payoff of 0 and P receives an expected payoff of the disposable rents of the organization.

Proof The proof follows the argument given in the text.||

7. References

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Figure 1: Sequence of Moves in Coalition-Formation when θ commonly-known

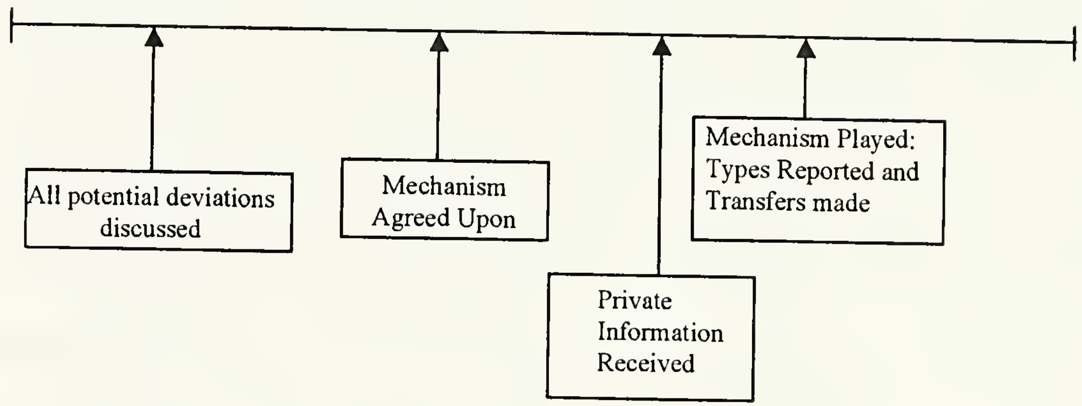


Figure 2: The Structure-less Organization

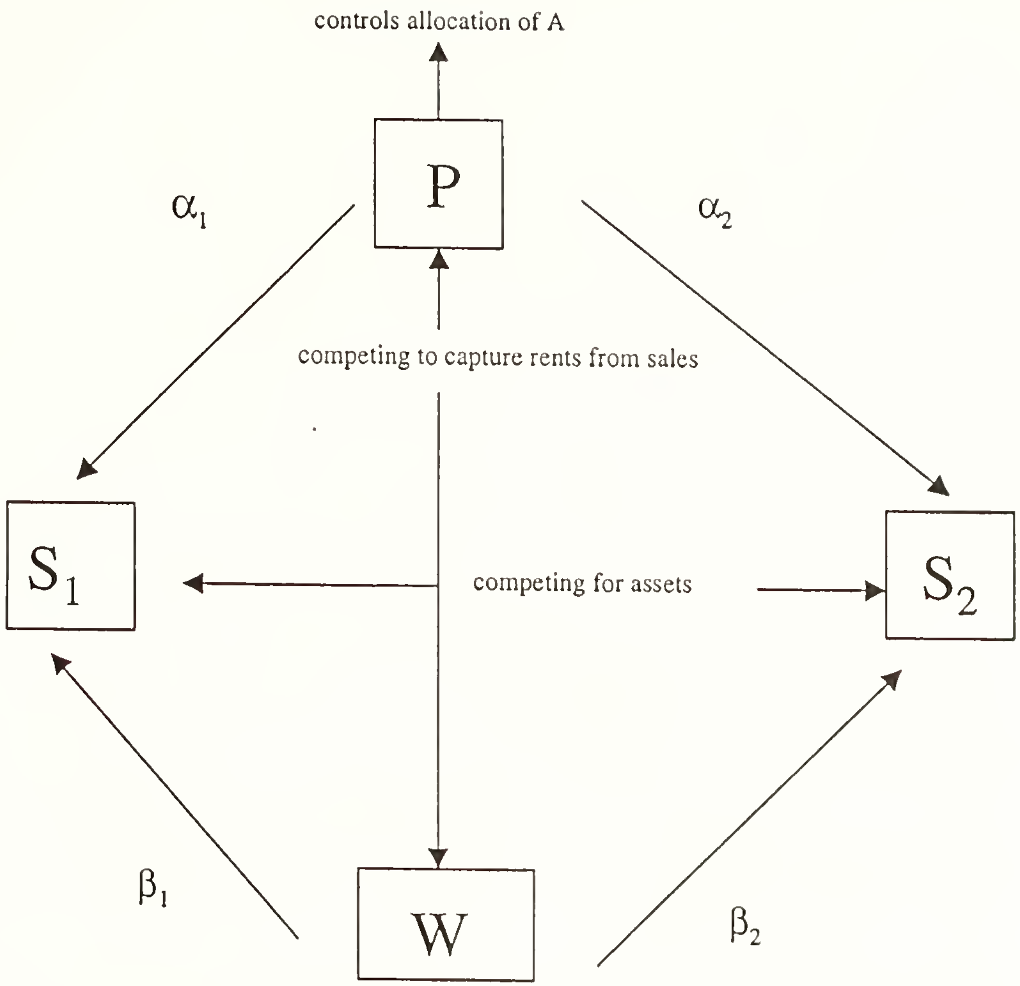


Figure 3: Sequence of Moves in Coalition-Formation when θ privately-known

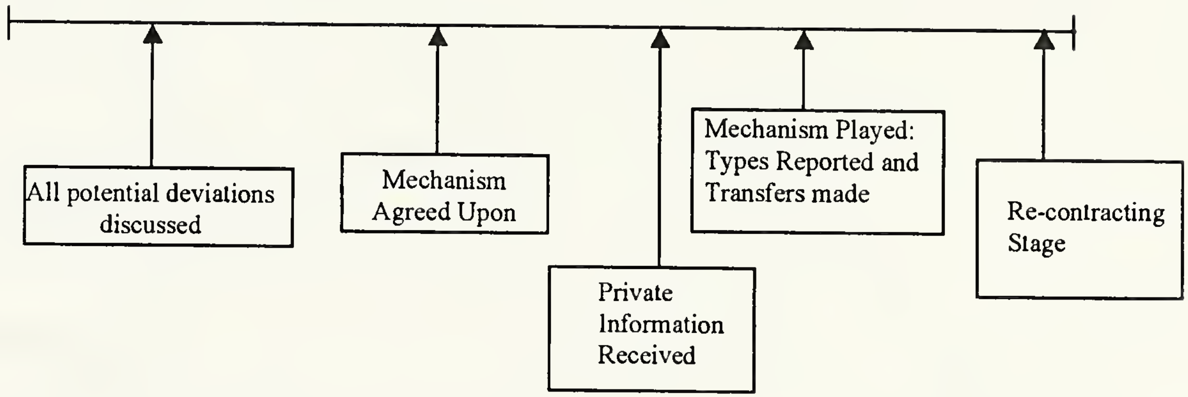
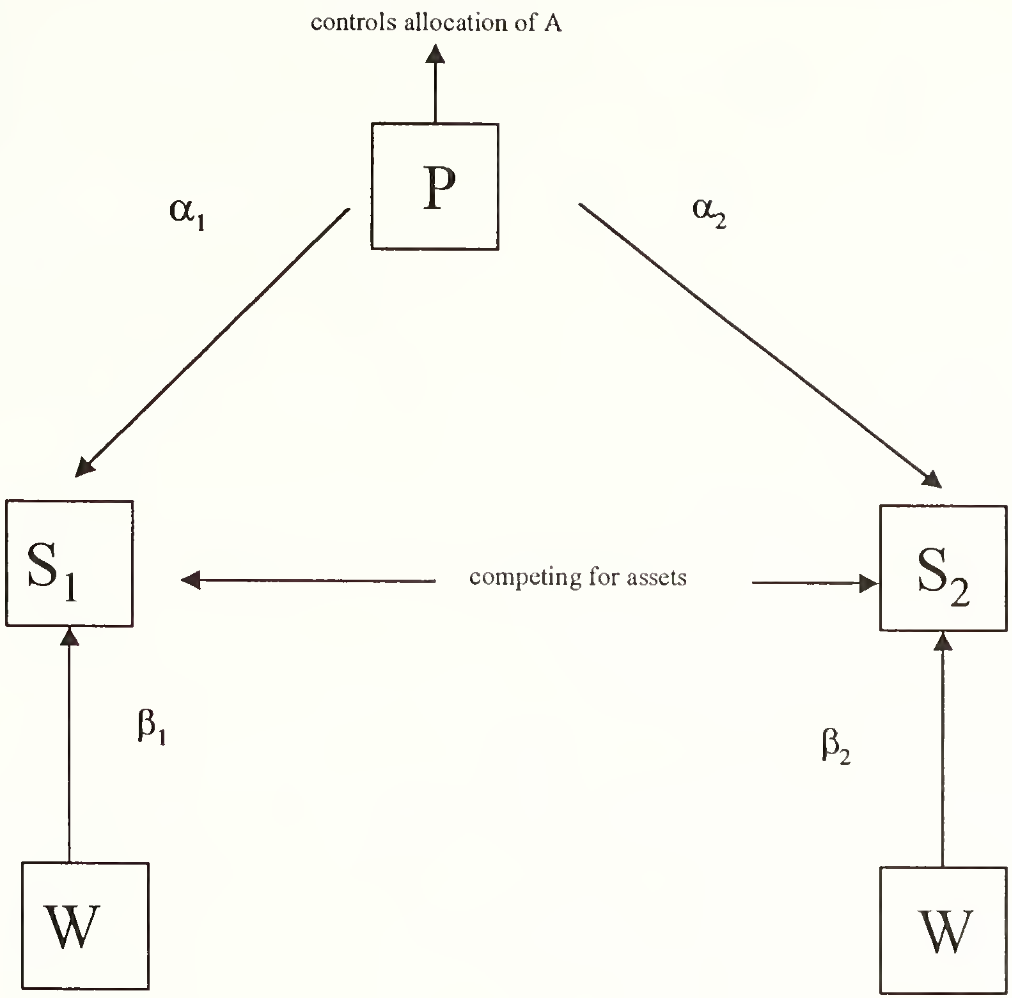


Figure 4: Organization with Optimal Authority Structure



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